



1 A number of ways to make payments across the Internet have  
recently sprung up to solve this problem. Most of these methods  
use procedures and protocols designed to make financial  
transactions on the Internet as confidential as possible, using  
5 encryption technology to make sure that no one can steal a credit  
card number. Typically, schemes for secure transactions take two  
approaches. One approach encrypts personal financial  
information, such as a credit card number, so that it can be  
transferred across the Internet in a manner that would not let  
10 unauthorized people read the data. The second method creates a  
system of cyber-dollars, electronic credits that only authorized  
merchants can redeem for real money.

The Secure Electronic Transaction protocol (SET) has been  
endorsed by VISA, MasterCard, American Express, Microsoft, and  
15 Netscape, among other companies. SET describes a way that people  
can shop online and have the purchases charged to their credit  
cards.

In addition to secured credit card transactions, a number  
of companies are working on electronic, or "cyber-dollar"  
20 scenarios that will enable consumers to purchase goods and  
services anonymously. That is, the consumer uses the digital  
equivalent of paper currency to make purchases and need not  
provide personal information such as, credit card or bank  
information to do so. Using this method of electronic payment,  
25 consumers buy electronic "coins" or "tokens" and use these  
specially marked and encrypted coins to make purchases.

Both credit card systems and electronic cash systems have  
their disadvantages. For example, most of the secure e-commerce  
web sites provide a secured socket layer (SSL) encryption method  
30 to protect customers' information when transmitted over the  
Internet. This method tends to protect the data being  
transmitted over the Internet by encrypting the data before it  
is transmitted. However, even if it is assumed that a hacker  
will not be able to break in this system, a remaining major  
35 concern is that merchants have buyers credit card information.

1 Customers use their credit cards to shop online from many online  
store. There are many ways these online stores can take  
advantage of this information. Furthermore, in case of a credit  
card fraud, it would be very difficult to find out who used the  
5 credit card without the permission of the card holder. Sometime,  
it is the employees or people who have access to the data in any  
of the e-commerce companies that a buyer had shopped.

Another concern is having too many credit cards. On  
average, a card holder has three credit cards. To solve the  
10 problem of having too many cards, many companies are trying to  
find the best way to store all of credit card and other  
information into a smart card, however, if the smart card is  
stolen or lost, then someone may gain access to all the credit  
card and personal information. However, smart cards for online  
15 shopping transmit credit card information online, even though,  
the information is encrypted with a smart card code. Similarly,  
merchants can still have access to the credit card information.  
Therefore, smart cards like regular credit cards, still provide  
the credit card information to merchants and transmit the  
20 information over the Internet, which may be intercepted by  
unauthorized hackers. Additionally, even with a smart card, the  
card holder needs to have the card or memorize the card  
information such as, the card number, expiration date, etc.  
Additionally, smart cards are prone to being lost.

25

#### SUMMARY OF THE INVENTION

The system and method of the present invention overcomes the  
disadvantages of the existing systems by using fingerprint as a  
password or a key to secure data resulting in the following  
30 advantages over the existing systems: convenience, flexibility,  
portability, different fingerprint sequences can be used for  
different purposes, can fit in any crypto algorithm as long as,  
the algorithm requires a password, and hardware independent.

In one embodiment, the invention extracts unique numerical  
35 information from a fingerprint called Fingerprint To Number (FTN)

1 gateway. A fingerprint is first scanned and the scanned image  
is enhanced. The blurred area of the image is restored and the  
enhanced image is binarized. The binarized image is then  
thinned. A core point in the image is detected and minutiae  
5 within a given radius from the core point are detected. A number  
is then extracted from the image by computing relation of  
minutiae to the core point.

In one embodiment, the present invention provides a computer  
data encryption/decryption device and program that uses a  
10 fingerprint minutiae generated password to encrypt/decrypt credit  
card information before sending the information over a computer  
network. The system uses the finger print along with a public  
key infrastructure (PKI) and some image processing to ensure the  
security of the user's accounts.

15 In one aspect, the invention describes a method for  
obtaining a numerical value from a fingerprint comprising the  
steps of: enhancing a scanned image of the fingerprint; restoring  
the enhanced image; binarizing the restored image; thinning the  
binarized image; detecting a core point in the thinned image;  
20 detecting minutiae within a predetermined radius from the core  
point; and extracting the numerical value by computing relations  
of the minutiae to the core point.

In another aspect, the invention discloses a fingerprint  
scanning device comprising: means for scanning a fingerprint for  
25 obtaining a fingerprint image; means for enhancing the  
fingerprint image; means for restoring the fingerprint image;  
means for binarizing the fingerprint image; means for thinning  
the fingerprint image; means for detecting a core point in the  
fingerprint image; means for detecting minutiae within a  
30 predetermined radius from the core point; and means for  
extracting the numerical value by computing relations of the  
minutiae to the core point.

General purpose computers, special purpose computers,  
networked computing systems, and/or special hardwares, such as

1 a Digital Signal Processor (DSP) chips are capable of performing  
the steps of the present invention.

#### BRIEF DESCRIPTION OF THE DRAWINGS

5 The objects, advantages and features of this invention will  
become more apparent from a consideration of the following  
detailed description and the drawings, in which:

FIG. 1 is an exemplary block diagram for the client/server  
architecture, according to one embodiment of the present  
10 invention;

FIG. 2 is an exemplary process flow diagram showing the use  
of a fingerprint to encrypt data, according to one  
embodiment of the present invention;

FIG. 3 is an exemplary registration process, according to  
one embodiment of the present invention;

FIG. 4 is an exemplary purchasing process, according to one  
embodiment of the present invention;

FIG. 5 is an exemplary process flow chart for merchant site  
information handling, according to one embodiment of the  
present invention;

FIG. 6 is a simplified system for a cardless secure  
transaction processing, according to one embodiment of the  
present invention;

FIG. 7 is an exemplary process flow chart for registration  
process, according to one embodiment of the present  
invention;

FIG. 8 is an exemplary flow chart for purchasing process,  
according to one embodiment of the present invention;

FIG. 9 is an exemplary process flow chart for merchant site  
information handling, according to one embodiment of the  
present invention;

FIG. 10 is an exemplary diagram depicting examples of how  
a numerical value is extracted from a processed image,  
according to another embodiment of the present invention;

35

1 FIG. 11 is an exemplary process flow for extracting a  
unique numerical information from a fingerprint, according  
to one embodiment of the present invention;  
FIGs. 12A-B are exemplary diagrams depicting a binarized  
5 imaged obtained from a gray scale image, according to one  
embodiment of the present invention;  
FIG. 13 is an exemplary diagram depicting a core point,  
according to one embodiment of the present invention;  
FIGs. 14A-B are exemplary diagrams depicting a transformed  
10 image, according to one embodiment of the present  
invention;  
FIGs. 15A-15D are exemplary diagrams depicting examples of  
how a color change is counted, according to one embodiment  
of the present invention; and  
15 FIGs. 16A-16B are exemplary diagrams depicting examples of  
how a numerical value is extracted from a processed image,  
according to one embodiment of the present invention.

#### DETAILED DESCRIPTION OF THE INVENTION

20 In one embodiment, the present invention is a system and  
method for extracting unique numerical information from a  
fingerprint. The system then uses the extracted number as a seed  
to generate a variable length of numerical information as a  
"password" to use with any encryption formula that requires a key  
25 or password to encrypt data. The length of the generated  
numerical information "password" depends on the resolution of the  
fingerprint scanning unit and the method of numerical information  
extraction algorithms. In one embodiment, the numerical  
information can be a combination of any number of fingerprints.  
30 Furthermore, the information can be more than one persons's  
fingerprint combination.

In one embodiment, the present invention uses a fingerprint-  
capturing device (scanner) to capture fingerprint image and then  
transforms it to a digital image. After image enhancements and  
35 pattern recognition processes, digital image is then transformed

1 into numerical information and applied into an encryption formula  
(algorithms). In another embodiment, the present invention  
provides fingerprint scanning and transforms the scanned image  
into a "minutiae" as digital data. This digital data is then  
5 used as a "secret key" in a cryptographic formula for data  
encryption and user authentication. The system creates a binary  
file based on this minutiae key and securely stores the binary  
file.

In one embodiment, the invention describes a cardless  
10 credit/debit card transaction processing system. The system can  
store multiple card information in a highly secured manner, thus  
eliminating any need to carry any credit card or debit card.  
Biometric methods are utilized to identify and authorized  
transactions in an encrypted and secure environment.  
15 Encryption/decryption methods may be applied using multiple  
fingerprint sequences rather than only one fingerprint. For  
example, a login fingerprint can be a left thumb fingerprint  
while the fingerprint authorization sequence may use the left  
second finger and the right thumb.

20 In one embodiment, a computer controlled system notifies  
users about their purchase detail information through a channel  
of delivery. These channels of delivery include: voice call,  
pager alert, e-mail, SMS (short messaging system), instant  
messaging system, facsimile, and the like.

25 In one embodiment, the present invention employs a public  
kiosk to provide access to Internet through an ISP. FIG. 1 shows  
a block diagram of a typical Internet client/server environment  
used by the users in one embodiment of the present invention.  
PCs (or public kiosks) 220a-220n used by the users are connected  
30 to the Internet 221 through the communication links 233a-233n.  
Optionally, a local network 234 may serve as the connection  
between some of the PCs 220a-220n, such as the PC 220a and the  
Internet 221. Servers 222a-222m are also connected to the  
Internet 221 through respective communication links. Servers  
35 222a-222m include information and databases accessible by PCs

1 220a-220n. In one embodiment of the present invention, a  
computer program for extracting a unique numerical value from a  
fingerprint and providing cardless secure credit transactions  
resides on at least one of the servers 222a-222m and is  
5 accessible by the potential buyers and credit card holders using  
one or more of the PCs 220a-220n.

In one embodiment of the present invention, each of the PCs  
(kiosks) 220a-220n typically includes a central processing unit  
(CPU) 223 for processing and managing data; and a keyboard 224  
10 and a mouse 225 for inputting data. A main memory 227 such as  
a Random Access Memory (RAM), a video memory 228 for storing  
image data, and a mass storage device 231 such as a hard disk for  
storing data and programs are also included in a typical PC.  
Video data from the video memory 228 is displayed on the display  
15 230 by the video amplifier 229 under the control of the CPU 223.  
A communication device 232, such as a modem, provides access to  
the Internet 221. Optionally, one or more of PCs 220a-220n may  
be connected to a local network 234. An Input/Output (I/O) device  
226 reads data from various data sources and outputs data to  
20 various data destinations.

Servers (hosts) 222a-222m are also computers and typically  
have architecture similar to the architecture of PCs 220a-220n.  
Generally, servers differ from the PCs in that servers can handle  
multiple telecommunications connections at one time. Usually,  
25 servers have more storage and memory capabilities, and higher  
speed processors. Some servers (hosts) may actually be several  
computers linked together, with each handling incoming web page  
requests. In one embodiment, each server 222a-222m has a storage  
medium 236a-236m, such as a hard disk, a CD drive, and the like  
30 for loading computer software. When a software such as the  
software responsible for executing the processes in FIGs. 2-8 is  
loaded on the server 222a, an off-the-shelf web management  
software or load balancing software may distribute the different  
modules of the software to different servers 222a-222m.  
35 Therefore, in one embodiment, the computer program responsible



1 for executing the present invention resides on one or more servers.

An exemplary web site location 235 is shown on server 222a in FIG. 1. In one embodiment of the present invention, a secure  
5 file including a finger print may be securely stored by a user by accessing web site 235 as described below in more detail. The web site 235 has a unique address that is used by the users to access server 222a (in this example) and the web site location on the server 222a. The computer software for executing the  
10 steps of the present invention may also partially reside on the web site 235.

An enormous amount of information is sent and stored over the Internet every day-everything from personal e-mail to corporate data to credit card information and other highly  
15 sensitive material. Because the information is sent in packets along public routers, the possibility exists that someone could intercept the information, or retrieve the information from the storage facilities. As a way to ensure that the sensitive material can't be looked at, the present invention uses  
20 sophisticated cryptographic system and method so that only the sender can retrieve the data from the remote storage facilities.

The Internet is a notoriously insecure network. Anything that is sent across it or stored in storage connected to it can be tampered with. This is of particular concern when  
25 confidential information, such as personal data and credit card numbers, is transmitted and stored across the Internet. Another related concern is that it can be difficult to know that the person sending the information across the Internet, such as credit card information, is really who he says he is. There are  
30 ways for people to forge identities and steal credit card numbers, and financial institutions and other businesses require ways to know that the person sending information really is who he says he is.

In one embodiment, the present invention uses finger print  
35 based encryption that uses finger prints as encryption keys. The

1 system then uses the encryption key to transmit data over the  
Internet. In public key cryptography, two keys are involved: a  
public key and a private key. Every person has both a public key  
and a private key. The public key is stored in a secure  
5 PKIserver and is not publicly available. This embodiment is a  
closed system where only the PKIserver can use the public key to  
identify the data is coming from the "real" source, not a fake  
source. However, the private key is kept secret on the person's  
computer. The public key can encrypt messages, but only the  
10 private key can decrypt messages that the public key has  
encrypted. The invention uses a binary file generated from  
scanning the user's finger print as the private key to encrypt  
the credit card information and decrypt the data.

In one embodiment, the invention uses digital certificates  
15 that use encryption to authenticate the person sending  
information, a credit card number, a message, or other data over  
the Internet. The system uses human fingerprint to digitally  
sign and encrypt the message sent to payment gateway. As a  
result, users can shop anywhere in the world, and there is no  
20 need to restrict a user to his own computer. When someone with  
a digital certificate goes to a site or sends e-mail, that  
certificate is presented to the site or attached to the e-mail,  
and it verifies that the user is who he claims to be. The  
information has been encrypted in a way that makes it unique to  
25 the user. In one embodiment, the system of the present invention  
utilizes the finger print of the user (explained in more detail  
below) to generate a unique digital signature to be used by that  
user to verify the authenticity of the user.

A typical financial transaction on the Internet works as  
30 follow. Suppose a buyer browses through an electronic catalog  
on a Web site and he decides to buy a book. To use the Secure  
Electronic Transaction protocol (SET) to pay for the book, the  
buyer needs a credit card from a participating bank and a unique  
"electronic signature" for his computer. This information will  
35 verify who the user is, i.e., what computer the signature is

1 coming from. However, because the certificate is installed on  
a user computer ,any person who has access to the user computer  
can use the user's account to purchase goods without user's  
authorization.

5 The system of the present invention alleviates this problem  
by utilizing the account owner's fingerprint for authenticating  
and authorizing the account owner. Furthermore the present  
invention eliminates fix location problem of today's verification  
10 any machine identification purposes. A potential consumer can  
freely shop anywhere around the world using any computer or POS  
system. Moreover, unlike SET, that can only be used on a card  
issuing bank that is a SET member, the system of the present  
invention is bank independent, meaning that any bank's credit  
15 card can use the system. This system does not need any bank to  
join or accept any specific rules or application.

For the system of the present invention, the merchant does  
not need to know where the order comes from nor the identity of  
the buyer is needed. Since the user uses fingerprint to verify  
20 and encrypt information, the system can easily authenticate the  
buyer. This design also protects unnecessary personal data  
leaks, specially when stored in a third party system, for  
example, the merchant's system.

The present invention uses "closed" PKI system for merchant  
25 identification purpose. The merchant sends verification to the  
buyer that the order has been made. The merchant's software  
creates an authorization request for payment and includes with  
the merchant's digital signature the transaction identifier and  
the PI received from the buyer. The software encrypts all of it  
30 and sends the encrypted request to the payment gateway. The  
payment gateway decrypts the messages and uses the merchant's  
digital signature to verify that the message is from the  
merchant. By examining the PI, it verifies that they have come  
from the buyer. The payment gateway then uses a bank card  
35 payment system to send an authorization request to the bank that

1 issued the buyer his bank card, asking if the purchase can be made.

When the bank responds that the payment can be made, the payment gateway creates, digitally signs, and encrypts an authorization (approval) message. This message is then sent to the merchant. The merchant's software decrypts the message and uses the digital signature to verify that it came from the payment gateway. Assured of payment, the merchant now ships the book to the buyer. Some time after the transaction has been completed, the merchant requests payment from the bank. The merchant's software creates a capture request, which includes the amount of the transaction, the transaction identifier, a digital signature, and other information about the transaction. The information is encrypted and sent to the payment gateway.

15 The payment gateway decrypts the capture request and uses the digital signature to verify it is from the merchant. It sends a request for payment to the bank, using the bank card payment system. It receives a message authorizing payment, encrypts the message, and then sends the authorization to the merchant. The merchant software decrypts the authorization and verifies that it is from the payment gateway. The software then stores the authorization that will be used to reconcile the credit card payment routinely when it is received from the bank.

25 There are many existing encryption algorithms such as, RSA, DSA, etc. All of these encryption algorithms involve altering the original data into different one by means of performing certain calculation on the original data. Some systems use hardware address or ID as a key, however, it requires the user to perform the encryption/decryption on the same machine.

30 A Public Key Infrastructure (PKI) algorithm uses a certification authority (CA) and issues a private key that resides in the user's computer and a public key that is obtainable by the receiver of the message. If the user wants to encrypt a message and send it to others, the user has to perform the encryption in his own computer. While the receiver of the

35

1 message can get the public key to decrypt the message anywhere around the world.

FIG. 2 is an exemplary process flow diagram showing the use of a fingerprint to encrypt data according to one embodiment of the present invention. In block 201, a fingerprint scanner scans human fingerprint "live scan" into an image format. Live scan is a fingerprint scanning process that detects human fingerprints by temperature, contact pressure, etc. Then, some image processing is performed to enhance the finger print image in block 202. Image processing includes noise reduction, image enhancement, thinning, minutia detection, etc. The digital image of the fingerprint is then converted into a binary number, as shown in block 203. The system then uses this number as "password" for an encryption algorithm to encrypt the target data, as shown in block 204. In block 205, data such as credit card information is encrypted using the fingerprint-based password.

In one embodiment, password length can be increased to improve security by using multiple fingerprints and with different sequence. For example, numbering fingers in 0-9, starting from left to right. Then, using the two thumbs will be "56" and using both small fingers will be "09". Furthermore, a larger number of fingers can be used in different sequence and frequency to obtain an even more secure system.

In one embodiment, the credit card information is stored in a data center, so that the user can access this data at anytime anywhere using Internet. The data is stored in an encrypted form which means user has complete privacy for her data. A compatible fingerprint and a computer program record new member's fingerprint minutiae for system login and identification purposes. A software program including a specific private key is used to obtain the member's fingerprint minutiae key, encrypt it with the private key and send it to the data center to complete the registration process. The private key is preferably hard-coded in the program. In one embodiment, an all-in-one

1 device, combines scanner and encryption module in a fingerprint reader unit, with hardware encoded key for encrypted transmission.

5 New member's fingerprint minutiae is sent to the data center in encrypted form with the private key that is sent with the membership package. In the data center, a public key that is stored with user ID in a secured database is used to decrypt the encrypted message. This message is a payload data including the encrypted fingerprint minutiae key from the user. The decrypted  
10 message (result) is the original minutiae from the user. This fingerprint is for future login verification purpose. This encrypted message is encrypted with specific private key (the one that was sent to the new member). If member's encrypted fingerprint minutiae key cannot be decrypted in the data center,  
15 new member needs to retry the process in order to complete the registration process.

Once registration is completed, the member only needs to type in a user ID and position his/her finger in the fingerprint reader. User ID is encrypted with member fingerprint minutiae  
20 and is sent to data center for login request. Then, the data center decrypts the user ID with the presorted fingerprint minutiae key. A portable fingerprint reader unit with Internet connection capability may be provided in the post offices (or any other convenience place) for the new member to complete the  
25 registration process.

In one embodiment, the system of the present invention (M1 system) provides services to both existing and new credit/debit card members. Customers register their banking information (like credit card information, debit card information, etc.) with  
30 system's Secured Relay Data Center. All customer information are stored in an encrypted form by means of their own fingerprints as a "key". When using this embodiment to purchase goods online, customers simply input their userID and their Login fingerprint scan. The Secured Relay Data Center then displays to the  
35 customer a pop up screen that includes data such as, "name of

1 card issuing bank" for the customer to choose from. After  
deciding which card to charged to, the customer then use the  
system to scan the fingerprint authorization sequence (may have  
more than one fingerprints). Banking information is then  
5 decrypted from the Secured Relay Data Center and is sent to the  
Merchant Bank for credit processing via line with security  
capabilities, such as ISO8583.

FIG. 3 illustrates an exemplary registration process  
according to one embodiment of the present invention. As shown  
10 in block 302, a customer may apply for a system account through  
mail, online registration, FAX, etc. Once an account is  
established, in block 304, the system checks to see whether the  
customer is the owner of the applied banking information, i.e.  
credit card, debit card owner etc. If the customer chooses to  
15 purchase a fingerprint scanning device, a fingerprint scanning  
unit along with the proper software is shipped to customer, as  
illustrated in block 306. In block 308, using the installed  
fingerprint scanning unit, the system sends the customer login  
fingerprint scan to the secured data center 312. If a  
20 fingerprint scanning device is not available to the customer, the  
customer may visit a service station (e.g., a post office, bank,  
etc.) to scan his finger print.

The first time fingerprint registration is encrypted by a  
"hard coded" private key in the fingerprint scanner (block 310),  
25 then decrypted later with the public key in the data center 312.  
In block 318, after successful login to the system, the customer  
is required to send in banking information and the fingerprint  
authorization sequence scan to a secured database. The  
fingerprint authorization may include more then one fingerprint  
30 with different sequences. Banking information is then encrypted  
using customer's fingerprint authorization as a "Key" and stored  
in the secured relay data center 316. As a result, only the  
customer can decrypt the banking information using his/her  
fingerprint.

35

1           FIG. 4 shows an exemplary purchasing process according to  
one embodiment of the present invention. The customer may  
purchase goods and services on any online store. Such store  
should have M1 Payment method (the above described embodiment)  
5   enabled. The customer can access M1 payment method form any  
computing device that has Internet access and has a compatible  
fingerprint-scanning device 426. (e.g., . mobile device 420, PC  
at home 422, public kiosk 424, etc.). In block 402, the customer  
enters his userID and the login fingerprint scan. The userID is  
10 encrypted with the login fingerprint and sent to the secured  
relay data center 416 for login purpose. The system then queries  
the database 418 for a list of all registered banking information  
by the customer. In block 404, a pop-up screen displays to the  
customer information including registered credit/debit card (bank  
15 name only, no number) information on file.

The customer can choose which card to use and then submits  
fingerprint authorization sequence scan, as shown in block 406.  
The encrypted card information is then retrieved from the secured  
relay data center database and is decrypted with customer's  
20 fingerprint authorization. Card information and purchase details  
are then encrypted and sent to merchant bank for credit  
processing, as shown in block 408. The credit information is  
processed and approval information is returned to the merchant  
(the online shop in this case), as shown in block 410. The  
25 system then passes the approval information to the Notification  
server and sends a purchase notification to the customer  
according to his/her preferences in block 412. The notification  
can be a voice call, pager alert, Fax etc. The matching server  
stores the login fingerprint and the customer registered banking  
30 information.

FIG. 5 depicts an exemplary process flow chart for merchant  
site information handling according to one embodiment of the  
present invention. Once in the merchant web site, the customer  
proceeds to check out the site and chooses an M1 payment method  
35 in block 502. The customer then enters userID and logs in the



1 fingerprint scan that is sent to the data center in encrypted  
form in block 504. In block 505, the userID is encrypted with  
login fingerprint and is transmitted to the data center via  
Internet with SSL. The server in the data center returns  
5 possible choices of credit/debit card issuing bank name in a pop-  
up screen, as depicted in block 506. The customer then chooses  
credit/debit card name and enters fingerprint authorization  
sequence in block 508. In block 509, the payload is encrypted  
with merchant side private key and is delivered to the data  
10 center.

The server in the data center then looks up credit card  
information and decrypts the information with customer's  
fingerprint authorization. The system then encrypts card  
information and payment details and send them to merchant bank,  
15 as shown in block 510. Merchant bank sends the credit process  
information to data center in block 512. The system then  
forwards approval information to merchant site via Internet with  
SSL. A notification with purchase details is then sent to the  
customer via customer pre-selected channel in block 514. The  
20 purchase detail is then returned to the merchant site, as shown  
in block 516.

FIG. 6 shows a simplified system according to one embodiment  
of the present invention. A customer visits an online shopping  
site 608 with M1 payment system enabled using a PC 602 or a  
25 mobile device 604 and an ISP 606. The customer can access an  
online shopping site via any computer device that includes a  
fingerprint reader. A double firewall infrastructure includes  
two firewalls 610a and 610b, preferably from two different  
firewall vendors. This is mainly to prevent hacker attacks on  
30 brand name firewall. Login fingerprint information is stored in  
a database 610a in a matching server 610. The matching server  
610 matches a user to a respective financial institution. A pop-  
up screen displays all registered credit/debit card names.  
Encrypted banking information storage 620 stores encrypted card  
35 information. Only the customer's own fingerprint (fingerprint

1 authorization) can decrypt this information. This action only  
occurs when a purchase action is initiated by the customer. A  
notification of purchase detail is then sent out to the customer  
via a notification server 612 and a notification communication  
5 center 614.

In one embodiment, the present invention provides service  
to both new and existing credit/debit card customers (M2 system).  
With this system, purchasing good and services at any point of  
sale (POS), including online shopping no longer require a  
10 physical card and pin. In this embodiment, the M2 system uses  
a fingerprint reader to collect customer's login fingerprint  
(similar to M1 system) and the card number is stored in a  
matching server located within individual's card issuing bank's  
site. This embodiment allows existing banking systems to remain  
15 intact, while incorporating the new biometric identification and  
encryption method to provide highly secured electronic  
transaction environment.

FIG. 7 depicts an exemplary flow chart for registration  
process, according to the above embodiment of the present  
20 invention. A customer submits credit/debit card in block 702.  
Existing cardholders may also use this service at their card  
issuing bank. This is due to credit card information being  
stored in a card issuing bank for the above embodiment. The  
application goes through normal credit card approval procedures  
25 according to individual bank, as shown i block 704. When  
application is approved, the customer uses a fingerprint reader  
to record login fingerprint scan and obtains a userID, as shown  
in block 708. In block 710, the login fingerprint is encrypted  
with the service center's private key and is sent to the data  
30 center for login and multi-card lookup purposes. The data center  
stores the userID and login fingerprint minutiae for multi-card  
lookup service in block 712. In block 714, the customer then  
enters fingerprint authorization sequence (may be multiple  
fingers) into the Matching Server located within the card issuing  
35 bank's data center. The Matching Server looks up credit card

1 information when a purchasing action is initiated by the customer. In this embodiment, customer's credit card information is stored in their card issuing bank and the M2 system does not know the customer's card information.

5 The Matching Server located at the card issuing bank's data center stores the userID and card information, as shown in block 716. This information may include card holder name, card number, expiration date, billing address, etc. When a purchase action occurs, the Matching Server uses fingerprint authorization  
10 sequence to decrypt the card information stored in the Matching Server. The system then sends that credit card information and purchase detail to the card issuing bank for credit processing. An optional transaction security check feature is provided to the customer. This feature requires the customer to record one more  
15 fingerprint scan (block 718) and stores it in a data Center, as shown in block 720. When the system detects an extensive usage of an account, the customer (Account holder) may be required to present the extra fingerprint scan as an extra security feature.

FIG. 8 depicts an exemplary flow chart for purchasing  
20 process according to the above described embodiment of the present invention. In block 802, the customer performs a purchasing action (POS or online store) with M2 Payment method selected. The customer then enters his userID and the login fingerprint scan in block 802. The data center looks for userID  
25 and the POS system displays to the customer a list of customer registered credit/debit card issuing bank name only, as shown in block 806. In block 810, the customer chooses which credit/debit card to use and submits fingerprint authorization sequence (i.e., one or more fingerprint). Purchase details and fingerprint  
30 authorization are encrypted with the data center's private key and then sent to customer's card issuing bank, as illustrated in block 812. The Matching Server decrypts the encrypted information with a public key obtained from the data center and looks up encrypted credit card information from the matching  
35 database according to the userID. The matching server then

1 decrypts the credit card information and sends it to the card  
issuing bank with purchase details for credit processing.  
Approval information is then returned to the merchant and the  
customer via the data center, as shown in block 814.  
5 Notification server then sends purchase notification to customer  
via a pre-selected communication channel similar to M1 system,  
as depicted in block 816.

FIG. 9 illustrates an exemplary process flow chart for  
merchant site information handling according to the above  
10 described embodiment of the present invention. After the  
customer enters in a userID and login fingerprint scan (block  
904), the merchant system redirects purchase detail, userID and  
login fingerprint encrypted with merchant's private key to the  
data center via an Internet connection, as shown in block 906.  
15 This merchant system and the POS device are depicted in FIG. 6  
as Merchant 630 and POS device 632. Also the merchant Bank site  
620 of FIG. 6 is replaced with the Card Issuing bank site in this  
embodiment. In block 908, the payload is encrypted in the data  
center with merchant's public key. The system then looks up  
20 credit/debit card listing (financial institute name only) from  
Matching Storage within the data center. The data center then  
returns card listing to the merchant's terminal, as shown in  
block 912.

The customer chooses a financial institute to be used from  
25 the card listing and then inputs fingerprint authorization  
sequence in block 914. The data center then encrypts the  
purchase detail with the private key. This information is then  
redirected to customer's choice of card issuing bank's Matching  
Server. The fingerprint authorization sequence for credit card  
30 information resides inside card issuing banks' Matching Server.  
This means the data center does not store fingerprint  
authorization sequence, that sequence only resides in the  
Matching server location typically, within the card issuing  
banks' site.

35

1       The Matching Server typically located within the card-  
issuing bank then decrypts the payload with the data center's  
public key, as shown in block 918. The system then matches the  
userID and fingerprint sequence to the received purchase detail  
5       and card information and sends it to card issuing bank for credit  
processing in block 922. In block 924, an approval code is then  
sent to the data center to notify the customer via pre-selected  
notification methods. The approval information is then sent to  
the merchant. In this embodiment (M2 system), all credit/debit  
10       card information retrieval and decryption are performed within  
the card issuing bank's data center and there is no need to  
modify the existing financial systems.

          A fingerprint is typically formed from composite curve  
segments. The top part is called "ridges" and the lower portion  
15       is called "valleys." The ridges and valleys alternate, flowing  
in a local constant direction. The "minutiae" are the small  
features formed by crossing and ending of ridges in the  
fingerprint ridges flow pattern. In other words, minutia refers  
to the ridge ending and bifurcation of a fingerprint pattern.  
20       Other important fingerprint features include: core and delta,  
which can be served as a "landmark" for orientation and act as  
a "singularity Point".

          FIG. 11 is an exemplary process flow for extracting a unique  
numerical information from a fingerprint, according to one  
25       embodiment of the present invention. In block 1102, gray scale  
fingerprint image are scanned from a fingerprint scanner.  
Typically a 500dpi (dot per inch) resolution is currently used,  
i.e., every inch of scanned image contains 500 pixels of  
information. After a gray scale image is acquired from the  
30       fingerprint scanner, the system performs an image enhancement  
step, as shown in block 1104. This process overcomes some  
undesired image degradation effects like wrinkles, scars, dirt,  
finger dryness, etc. In one embodiment, this step includes  
enhancing contrast and edge of each ridge. Then, an enhanced  
35       image is acquired using histogram equalization process. The

1 histogram equalization process is well know to people skilled in  
the art of image processing. The noise in the image is then  
filtered out. The ridge is then distinguished from the blank  
area (valley) by sharpening the edges of the ridge. Finally, the  
5 rough edges of each ridge are smoothen out.

In block 1106, the blurred image acquired during scanning  
is restored and the noise is filtered out again. The geometric  
distortion is corrected and, inverse filtering and least means  
square filtering, such as the well-known Wiener filtering are  
10 then applied.

Before thinning the image lines, gray-scale image should be  
transformed into binary (black and white) image. As shown in  
block 1108, the gray scale image is converted to a black-and-  
white image through a binarization process. Gray-scale image  
15 typically has an intensity level between 0 to 255. Intensity  
level 0 means black and intensity level 255 means white. (for  
gray-scale, intensity level can be regarded as a degree of  
brightness) As a result of converting gray scale image into  
binary image, the image lines are changed to black and between  
20 the lines are filled with white. If scanned image has lines with  
similar intensity level, the image can be easily transformed by  
setting a threshold of a certain intensity level. In this case  
if the line's intensity level is lower than that of threshold,  
it is changed into black and the blank area are filled with  
25 white.

In most cases, however, it is very difficult to obtain a  
clear image that includes lines with similar intensity levels.  
To overcome this problem, the method and system of the present  
invention performs the following steps. The image is partitioned  
and divided into several small areas. Then, an average intensity  
30 level of lines within an area is calculated. This average  
intensity is set as a threshold and the gray-scale image of the  
area is transformed to binary image. This process is then  
repeated for each partitioned area until binarization is

35

1 completed. FIG. 12B depicts an exemplary binarized imaged  
obtained from a gray scale image of FIG. 12A.

A binary to skeleton processing, called "thinning" may also  
be performed on the image, as illustrated in block 1110. A  
5 skeleton image is produced by eroding the objects within a binary  
image until they are one pixel wide. In other words, the width  
of the black lines are thinned to 1 pixel. The advantage derived  
from using a skeleton image is that extraction of ridge features  
becomes a relatively straightforward procedure based on tracing  
10 line segments. In one embodiment, the well known method  
described in T. Y. Zhang and C. Y. Seun, A Fast Parallel  
Algorithm for Thinning Digital Patterns, journal of  
Communications of ACM, 1984, 9, 236-239, the entire contents of  
which are hereby incorporated by reference; is used to perform  
15 the thinning.

After a skeleton image is generated from the gray scale  
fingerprint image, the core point of the fingerprint is  
determined in block 1112. A core point is defined as center of  
a fingerprint, where the direction lines meet each other, or on  
20 ridge line, as shown in FIG. 13. To detect the core point of an  
image, a core area needs to be detected first. To detect a core  
area, the image is first segmented, i.e., the thinned image is  
divided into square areas, for example areas of 8x8 pixels with  
only one or two black lines.

25 This process shortens the time required for processing an  
image. For example, using the above segmentation, it takes 1/64  
of the time required for processing a 256x256 pixel image without  
segmentation to search the same image. After segmenting the  
image, a Fast Fourier Transform (FFT) process is applied to each  
30 square area. The FFT process enables a computer program to  
recognize a line in a given area as a combination of dots, and  
also recognize the density of dots along a line. For example,  
even on the same line, the density of dots may be high on some  
area and low on other areas. A direction line vertical to the  
35 tangent of a given line in each segment is then extracted. This

1 line represents the direction of a line that can be obtained by  
slicing the line at a given point. That is why FFT process is  
applied to fingerprint image.

As a result of the above process, the image of the  
5 fingerprint is replaced with the combination of straight lines  
crossing from one side to the opposite side of the square area,  
as shown in FIGs. 14A-14B. The straight lines are then  
classified into 4 types; vertical, horizontal, a slope with left  
end high, and a slope with right end high. Each type of line is  
10 numbered from 0 to 3 in order. As a result, the fingerprint  
image is transformed into a matrix of 32x32(squares). The matrix  
is then processed by the column using the following two methods.  
Note that, a column which includes core area has the largest  
number of squares which are filed with vertical direction lines.

15 A. Core area exists on a column which has the most squares  
with number zero (vertical direction lines), or

B. Core area exists on a square whose upper squares in the  
same column all have number zero.

As a result of the above methods, several squares may be  
20 obtained. Core point exists on the square that meets the  
condition of definition B.

To detect the core point (pixel) within the detected core  
square, the detected core square obtained above, together with  
its neighboring squares are further segmented to smaller squares  
25 of 4x4 pixels. The above process for detecting core square is  
applied to the smaller square(s) to detect a smaller core square.  
The highest pixel on a smaller core square that is on the ridge  
line is the core point (pixel).

After the core point is detected, the minutiae have to be  
30 detected. Although, every fingerprint image has several  
minutiae, in one embodiment, only the bifurcation minutiae are  
detected. First, every 3x3 pixel window is processed to detect  
connectivity of the pixels within each window. The number of  
times that color changes from block to white is then counted.  
35 FIGs. 15A-15D depict examples of how the color change is counted.



1 In FIG. 15A, the color changes from black to white twice, i.e.,  
B to C, and F to G for a line. Thus, the central pixel (A) is  
tagged with a number 2. In FIG. 15B, the color changes from  
black to white only once, i.e., B to C, for a termination. Thus,  
5 the central pixel is tagged with a number 1. In FIG. 15c, the  
color changes from black to white three time, i.e., B to c, D to  
E, and F to G for a bifurcation. Therefore, the central pixel  
is tagged with a number 3. Finally, in FIG. 15D, the color  
changes from black to white three times, i.e., B to C, D to E,  
10 and G to H for a bifurcation. As a result, the central pixel (A)  
is tagged with a number 3. Thus, the pixels flagged with a  
number 3, are bifurcation minutiae where a ridge splits. Next,  
pixels with bifurcation are sorted by the order of their distance  
from the core point.

15 The final process is extracting a unique number from the  
image, as shown in block 1116 of FIG. 11. Some exemplary methods  
to accomplish this task are described below. The first method,  
numbers the pixels with bifurcation by the order of their  
distance from the core point, b1, b2, b3, b4, b5, b6, ..., etc.  
20 The distance between the core point and b1 = d1, and distance  
between b1 and b2 = d2 are calculated. Next, a circle with core,  
b1 and b2 on its circumference is drawn, and its radius r1 is  
calculated, as shown in FIGs. 16A and 16B. The first part of the  
numerical information, d1, d2, r1 is acquired in order. Then,  
25 the distance between b2 and b3 = d3 is calculated, a circle with  
b1, b2 and b3 on its circumference is drawn, and the radius r2  
is calculated. The second part of the numerical information, d3,  
r2 is then obtained in order. Then, the distance between b3 and  
b4 = d4 is calculated, a circle with b2, b3, and b4 on its  
30 circumference is drawn, and the radius r3 is calculated. The  
third part of the numerical information, d4, r3 is then obtained  
in order. The above procedure is repeated with all bifurcation  
pixels within a certain distance from the core point. As a  
result, the number obtained from the fingerprint is in the form  
35 of d1d2r1d3r2d4r3d5r4 . . .

1 A second exemplary method for extracting a unique number  
from the image is shown in FIG. 10. This method re-orientates the  
image to a direction, for example, parallel to y-axis. Then,  
5 from the detected core point, on a circle with a radius  $r$ ,  
sampling points are obtained. A sampling point refers to a  
vector of ridge flow pattern (flow direction), as shown in FIG.  
10. Eight sampling points information are then combined into a  
numerical value, as shown in FIG. 10.

10 According to a third exemplary method, from the detected  
core point, a circle with a radius  $r$  is reached and minutiae in  
different segments within that radius are detected. Then, the  
numbers of ridges between the core point and the reference  
minutiae are counted, and added up to obtain the numerical  
value.

15 The above method may be carried out using a general purpose  
computer, a special purpose computer, a networked computing  
system, or a special hardware, such as a Digital Signal Processor  
(DSP) chip. As described above, any or all of the hardware for  
performing the above steps may be embodied in a single  
20 fingerprint scanner device. After a unique numerical value is  
determined from the fingerprint, the numerical value may be used as  
a password, or a key that is used by an encryption module for  
data encryption/decryption, or other data security purposes.

25 It will be recognized by those skilled in the art that  
various modifications may be made to the illustrated and other  
embodiments of the invention described above, without departing  
from the broad inventive scope thereof. It will be understood  
therefore that the invention is not limited to the particular  
embodiments or arrangements disclosed, but is rather intended to  
30 cover any changes, adaptations or modifications which are within  
the scope and spirit of the invention, as defined by the appended  
claims.